

Radiometric Calibration Techniques for Signal-of-Opportunity Reflectometers



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Transmitted electric field field as quasi-monochromatic phasor

$$E_i(t, R) = \hat{p}_i \left(\frac{P_i G_i}{4\pi} \right)^{1/2} \frac{e^{-jkR}}{R} a(t - R/c) e^{j2\pi f_D t}$$

Frisis loss Doppler shift referenced to observer

MOTIVATION

- Internal Calibration
 - Stabilizes receiver gains and offsets
 - Measures correlation efficiency
 - Defeats fluctuations with rapid and periodic updates
- Electronic Calibration Sources
 - Reference switch
 - Common noise source
 - Applicable to general SoOp reflectometers, e.g. [2].
- Similar to Conventional Microwave Instruments
 - L-band radiometer and scatterometers (e.g., [3]–[4])
 - Reference switches, noise diodes and loop-back circuits

METHODOLOGY

- Reference switching
 - Overcome thermal and 1/f fluctuations
 - Allows removal of receiver noise offset
 - Useful for low SNR direct antenna configurations
- Noise source firing
 - Allows measurement of receiver gains and correlation efficiency
 - Cross-power appears at zero delay
 - Simultaneously observe reflected cross-power when delay difference is much larger than coherence time of signal

REFERENCES

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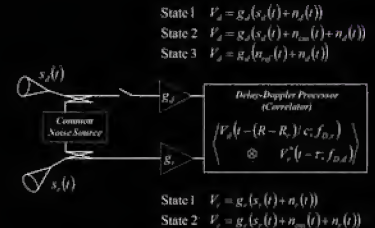
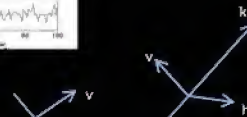
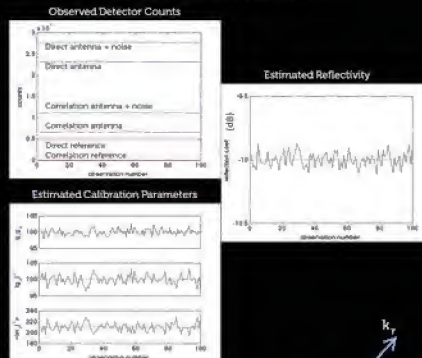
ABSTRACT

Bi-static reflection measurements utilizing global navigation satellite service (GNSS) or other signals of opportunity (SoOp) can be used to sense ocean and terrestrial surface properties. End-to-end calibration of GNSS-R has been performed using well-characterized reflection surface (e.g., water), direct path antenna, and receiver gain characterization [1].

Here, we propose an augmented approach using on-board receiver electronics for radiometric calibration.

Using similar techniques long-term (days to weeks) calibration stability of the L-band scatterometer and radiometer on Aquarius/SAC-D has been achieved better than 0.1% [5]. Similar long-term stability would likely be needed for a spaceborne reflectometer mission to measure terrestrial properties such as soil moisture.

SIMULATION RESULTS



SIMULATION & CALIBRATION

• Simulation parameters (static ground system)

Instrument parameters in units of counts (correlator output) and Kelvins (PAB)			
Antenna Gains	0 dB	SNR of direct look	10 dB
RF Gain	100	Receiver BW and Signal Type	10 MHz GPSK
Receiver noise temp	200	Reference load temperature	280
		Noise source effective temp.	450

• Calibration Equations

$$g_d g_r^* = [K_{rd}(\text{State 2}) - K_{rd}(\text{State 1})] / T_{CNS}$$

$$|g_d|^2 = [K_{dd}(\text{State 2}) - K_{dd}(\text{State 1})] / T_{CNS}$$

$$\langle |n_d|^2 \rangle = K_{dd}(\text{State 3}) / |g_d|^2 - T_{ref}$$

Cross-correlation function with range-tracking

$$\text{Receiver gain ratio} \quad \text{Reflectivity} \quad |\Gamma|^2 = \frac{G_d}{G_r} \left| \frac{g_d}{g_r} \right|^2 \left| \frac{K_{rd}((R_r - R)/c)}{K_{dd}(0) - \langle |n_d|^2 \rangle |g_d|^2} \right|^2$$

Antenna gain ratio Offset caused by sky and receiver noise

Auto-correlation function at zero lag

(Doppler-shift notation removed for simplicity – ground-based case)

